Historic, archived document

Do not assume content reflects current scientific knowledge, policies, or practices.

SHOUT
SHARE
IT

UNITED STATES DEPARTMENT OF AGRICULTURE

# BULLETIN No. 256

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C. PROFESSIONAL PAPER July 27, 1915.

U. S. Department of Agriculture
LIBRARY
RECEIVED

# KATYDIDS INJURIOUS TO ORANGES IN CALIFORNIA.

By J. R. HORTON and C. E. PEMBERTON,
*Scientific Assistants, Tropical and Subtropical Fruit Insect Investigations.*

## INTRODUCTION.

There are at the present time in the San Joaquin Valley of California over 43,000 acres of land devoted exclusively to the cultivation of citrus. The citrus strip lies along the Sierra foothills between Bakersfield and Fresno. Although some citrus trees have been grown in this area for more than 25 years, most of this great acreage has been planted in the last 15 years. The transformation of this strip of land from a semiarid grain-growing belt into an irrigated fruit-growing area has so changed the status of certain formerly obscure species of insects native to the locality as now to bring them into prominence as pests.

One of the more important of these species is the fork-tailed katydid, *Scudderia furcata* Brunner. The amount of damage done by this insect has increased considerably since 1910, when it first came to the attention of the senior author. In 1912 it caused a loss in several orchards of a full fourth of the crop.

Associated with the fork-tailed katydid in the orange groves and closely resembling it is the angular-winged katydid, *Microcentrum rhombifolium* (Sauss.). This insect is also responsible for a certain amount of injury to orange trees annually, feeding voraciously, as it does, upon the leaves. It is, however, of much less importance than the former, and is treated here rather because of close association with and resemblance to the fork-tailed katydid than on account of its economic importance. No distinction has heretofore been made between these two species in the orange groves of California.

## THE FORK-TAILED KATYDID.

### NATURE AND EXTENT OF INJURY.

The fork-tailed katydid (*Scudderia furcata* Brunner), so named from the peculiar forked appendage at the tip of the abdomen in the male,

NOTE.—Technical descriptions of two katydids causing serious damage to oranges in California are contained in this bulletin. Remedies and methods of control are discussed.

is so large that a day's feeding by a single individual may mean the destruction of several small oranges. Once an orange is attacked it is invariably rendered unfit for sale, and therefore usually left on the ground in the field at picking time.

The young katydids are on the trees and actively feeding at about the time the latter are beginning to lose their petals, and the injury usually begins at this stage. The insect will sometimes attack the blossom buds, generally gnawing a hole through the petals to reach the pistil and ovary, these organs often being destroyed in a considerable number of blossoms (figs. 1, 2). The petals themselves have apparently but little attraction for the insect.

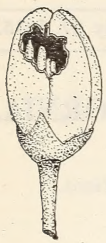

FIG. 1.—Orange bud injured by katydids. (Original.)

Whenever as many as 15 or 20 of the nymphs are found on a tree, the injury to the immature fruits becomes quite noticeable and a quantity badly chewed will be found on the ground (Pl. I, fig. 1). The injured oranges usually have been more than one-third destroyed or have received one or more holes large enough to admit the head and thorax of the slender katydid nymphs, such holes often extending entirely through the oranges. Many other oranges which have been two-thirds or more eaten away will be indicated by the portions remaining on the trees. The oranges which have been only slightly chewed when small and those which receive the injury after they are considerably grown and have "set" firmly to the tree remain to ripen only to be "culled" out either at picking time or in the packing-house. At picking time many of these damaged fruits are conspicuous owing to the clean-cut circular holes in the rind, which vary from the size of a dime to about that of a silver dollar (Pl. I, fig. 2; Pl. II, fig. 1). The insects have the habit, however, of chewing into the larger fruits from the side toward the tree trunk, seeking the shade and also protection from birds, and the injury may not then be noted until the fruit is picked. The holes in the more mature fruits, as in the very young ones, are often deep, extending through the rind and rag, well into the pulp. Many oranges are split wide open as the result of katydid injury inflicted when they were only about one-fourth matured, due to inability to expand along the dried edges to accommodate growth (Pl. II, fig. 2). All oranges which have been attacked after the crop has thoroughly set mature with the sound fruit, on the trees, and although edible they must be considered a dead loss, since they are unfit for shipment.

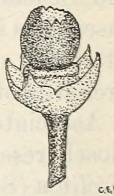

FIG. 2.—Young Navel orange from which the pistil remains and part of the fruit has been eaten by katydids. (Original.)

Examination in the orchards of hundreds of boxes of oranges throughout the San Joaquin Valley during the picking seasons of

1911 and 1912 showed the injury to be very widespread. Very few orchards were examined which failed to indicate the presence of this katydid by the unsightly chewed fruit, either in the boxes or discarded as worthless upon the ground about the trees (Pl. II, fig. 2).

In 1912, before the picking season commenced, an examination was made of all the fruit on 10 or more trees in each of 53 orchards of Washington navel oranges scattered throughout the orange district to determine the total injury to the mature fruit. Only 3 of these orchards were entirely free from katydid-injured fruit. In 3 of the remaining orchards the damage, though present, amounted to less than 1 per cent. In the remaining 47 orchards from 1 per cent to 39 per cent of the maturing crop was rendered totally unfit for sale by the katydids. Fourteen of the 47 orchards suffered a loss of 10 per cent or more of the crop. The total loss of fruit from this cause for the 47 orchards averaged 8.2 per cent of the entire maturing crop. These estimates do not, of course, include the very young fruits which are completely destroyed soon after the petals are off, and this loss is rarely noted at all by orange growers.

The orchards in which the injury is excessive are not necessarily in isolated locations, as has been supposed, nor are they growing under any unusual conditions. The katydid, however, appears to be slightly more abundant in the foothills regions, and it shows some preference for young and vigorously growing orchards.

Several groves which had previously suffered but slightly from katydids were called to the attention of the writers in 1911 and 1912 because of the increasing injury. Thus an orange grower informed the writers that he had seen the familiar circular holes cut in the fruit by katydids on his place for 14 years. Such a small percentage of fruit was affected, however, that he had paid no special attention to it until the fall of 1911, when he noted a material increase in injury. Just after the crop was picked in 1912 a visit was made to his orchard and the injury found much worse than in 1911. The pickers had just finished a 6-acre plat of young navel trees, from which they had discarded 12,000 oranges because of katydid injury. About 100 boxes of oranges were therefore ruined in this 6-acre block of trees, and as 800 boxes of good oranges were picked from these trees a complete loss of 11 per cent of the mature crop plus an undetermined percentage of young fruits and blossoms which might have become fruit was sustained. A 15-acre orchard of young Washington navel trees, which were but slightly infested in 1911, became seriously infested in 1912. When the final picking was made, 533 boxes of good oranges were secured from the orchard, while approximately 175 boxes, 21,000 oranges by count, were rejected as worthless because of splits, gashes, and holes caused by katydids.

The most striking example of injury by this katydid that has come to the attention of the writers was that of a navel-orange grove so

grossly infested in 1911 that 57 per cent of all the mature fruit was ruined. This was determined by actual count made at picking time. Many undeveloped, badly chewed oranges on the trees and the usual dried remains of other riddled fruits on the ground were not taken into account in this examination. These trees, which should have produced, at the very least, 2 boxes of oranges each, averaged only about 7 sound oranges per tree. In 1912 the injury was again very great in this orchard. A large amount of fruit was chewed and destroyed while still small, and the average number of oranges was but 9 per tree after all dropping had ceased and the fruit had matured.

It should be mentioned that, to the present time, the most severely damaged orchards are generally those in which the trees are 10 years of age or younger, although several of the older orchards suffered greater injury in 1912 than in any previous season.

*Injury to Valencia oranges.*—Examination of all the fruit on several trees in each of 15 Valencia orange groves showed this variety quite as susceptible to attack by katydids as the various navel types, the percentage of injury being practically the same in both.

*Injury to foliage* (Pl. III, fig. 1).—The fork-tailed katydid, as well as the angular-winged katydid, feeds during its entire life upon the leaves and stems of orange trees. It selects by preference the new, tender growth, filling the leaves with holes and often completely destroying the stems. The injury to foliage has not been serious except on trees where the nymphs were unusually numerous.

### FOOD PLANTS.

Under the conditions prevailing in the San Joaquin Valley citrus area, the fork-tailed katydid feeds almost exclusively upon the sweet oranges, where at all times the food supply is abundant and attractive. It has not been taken upon any other variety of citrus. Weeds are rarely allowed to grow in the orchards and, except in early spring, do not flourish on the unirrigated lands surrounding them. The insect has not in a single instance been found upon native weeds.

On one occasion, in October, 1911, the senior author heard a male of *Scudderia furcata* stridulating in a patch of string beans. Examination of the plants disclosed two adult females, and a bean leaf was found which contained two eggs. The following month he found eggs of the species in the leaves of apple and peach trees growing near orange trees. The insect was reported to the writers by an orchardist as injuring grapevines on his place. This report was verified and the injury found upon both leaves and berries.

Other writers have reported the insect as occurring upon "weeds," "coarse grasses," "thickets," "hedges," etc. Its food plants undoubtedly comprise widely different species in various sections of the United States. Under the name *Scudderia curvicauda* (De Geer) it

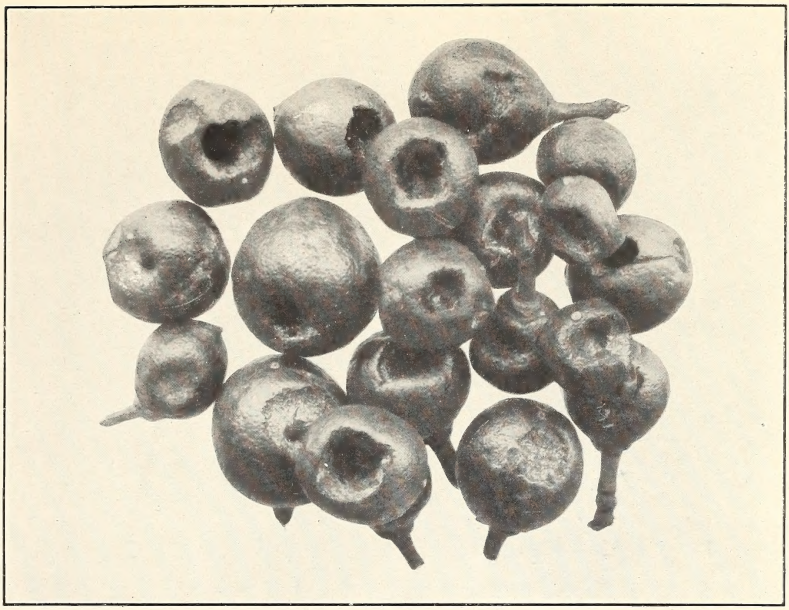

FIG. 1.—YOUNG NAVEL ORANGES RIDDLED WITH HOLES BY KATYDIDS. (ORIGINAL.)

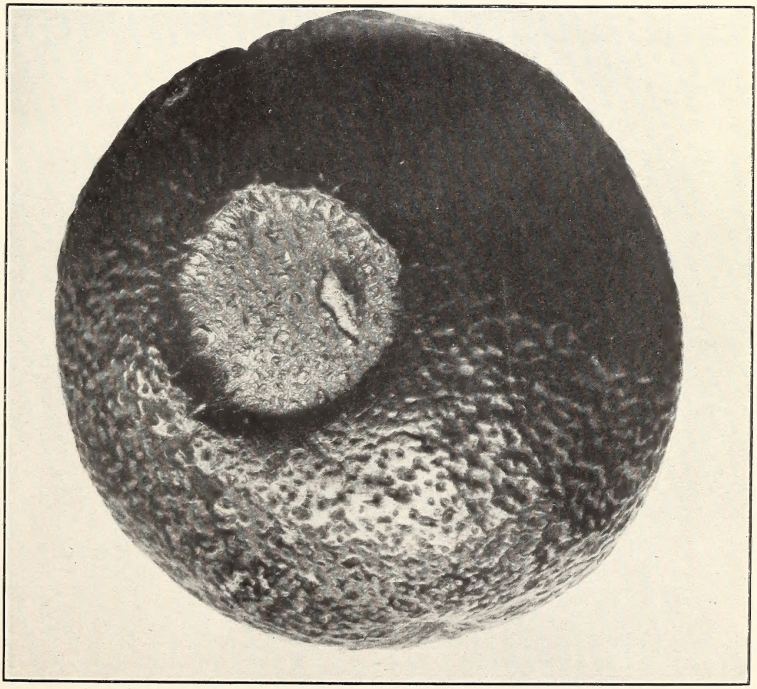

FIG. 2.—RIPE ORANGE SHOWING KATYDID SCAR AND THE BEGINNING OF SPLITTING. (ORIGINAL.)

INJURY TO ORANGES BY KATYDIDS.

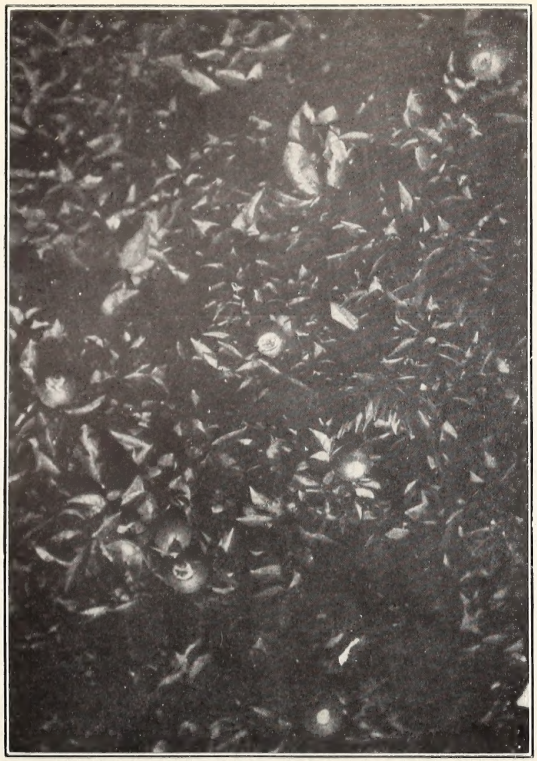

FIG. 1.—ORANGE TREE SHOWING OUTSIDE FRUIT INJURED BY KATYDIDS. (ORIGINAL.)

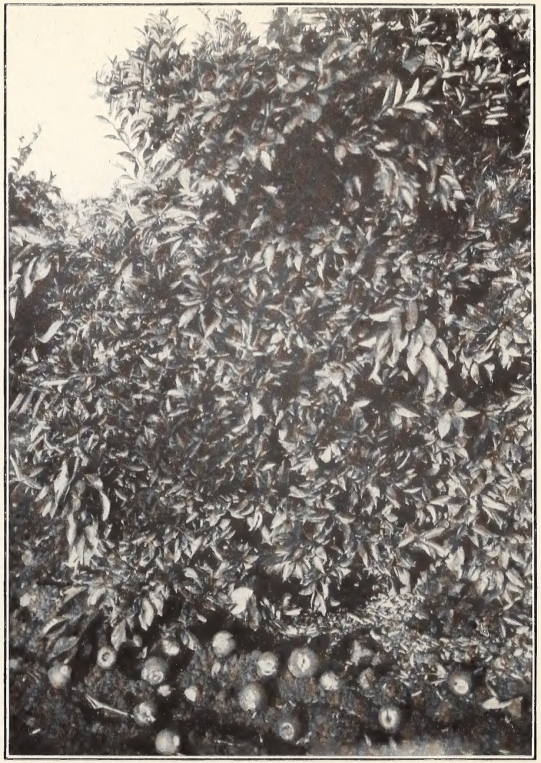

FIG. 2.—ORANGES INJURED BY KATYDIDS AND DISCARDED ABOUT THE TREES AT PICKING TIME. (ORIGINAL.)

INJURY TO ORANGES BY KATYDIDS.

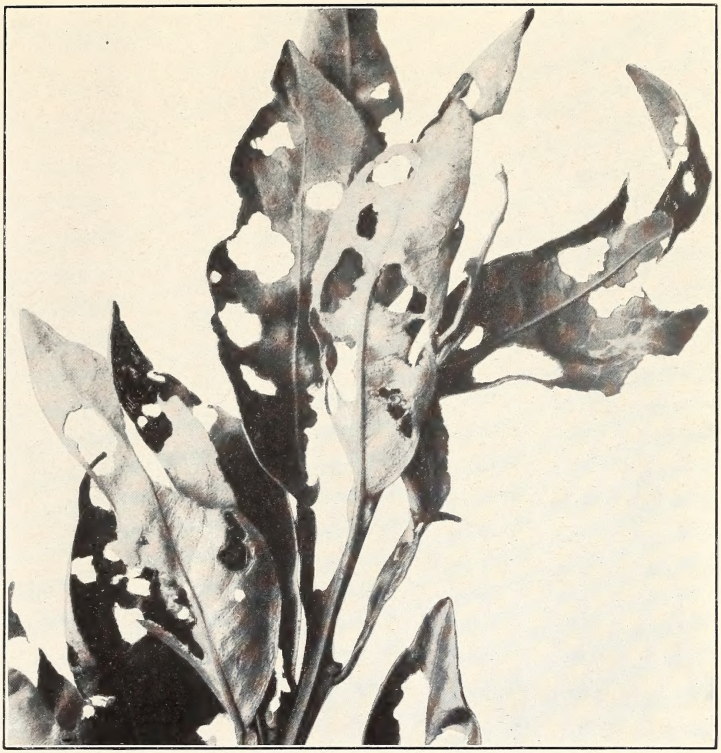

FIG. 1.—ORANGE LEAVES INJURED BY KATYDIDS. (ORIGINAL.)

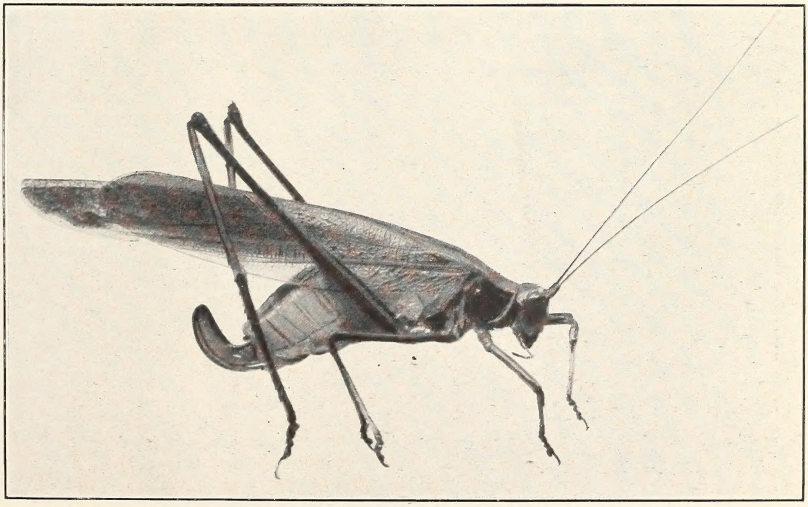

FIG. 2.—THE FORKED-TAILED KATYDID (SCUDDERIA FURCATA): ADULT FEMALE. ABOUT TWICE NATURAL SIZE. (ORIGINAL.)

THE FORKED-TAILED KATYDID AND DAMAGE TO ORANGE LEAVES.

has been reported by Riley[1] as feeding mostly on oak leaves and showing a preference for depositing its eggs therein.

## LIFE HISTORY AND HABITS.

### The Egg.

The egg (fig. 3) may be described as follows: Length, 4.5 mm.; breadth, 1.87 mm.; greatest thickness (when first deposited), 0.5 mm. Light gray; smooth, glistening; flat, ovoid, slightly reniform.

The egg is completely hidden from ordinary observation in the plant tissues; in fact, most eggs are inserted into the edges of the older and rather tough leaves, between the upper and lower surfaces. They are at first difficult to detect, but after practice their presence may be recognized by certain outward indications. The edge of the leaf where the egg is inserted is generally slightly chewed away, and with a lens the sharp tip of the egg may often be seen protruding from the cut. When the chewed places are not in evidence, the presence of an egg may be recognized by a slight oval swelling in the edge of the leaf. More rarely from one-fourth to one-half of the egg may be found protruding from the edge of the leaf. Occasionally two eggs are deposited side by side, and in course of growth they may break through the epiderm and remain exposed along an entire side. A suspected leaf, when held to the sun, will show the complete outline of any eggs which may be present. Eggs are occasionally found inserted into the angular edges of tender orange stems. At times the female eats a hole through a leaf and deposits eggs in the edge of the hole. Most eggs will be found in leaves well concealed within the spread of the tree, being thus protected, as well as may be, from enemies and frost. The number deposited in a single leaf ranges from 1 to 10, rarely more than 10; the average greatest number being but 3.

Fig. 3.—Eggs of the fork-tailed katydid (*Scudderia furcata*) in position in an orange leaf. About twice enlarged. (Original.)

During the first warm days of spring the eggs begin to swell through the development of the embryo. Shortly before hatching the egg is almost three times as thick laterally as when first deposited, the swollen areas in the leaf being therefore much more easily detected at this time than in fall or winter. In hatching, the two lateral halves of the eggshell separate along the outer third of their length, and the nymph slowly forces its way out head foremost. Experiments with a large number of eggs showed that hatching may take place even in leaves which have fallen to the ground and become dried out, provided they are kept fairly moist by exposure to the

[1] Riley, C. V. Sixth Annual Report on the Noxious, Beneficial, and other Insects of the State of Missouri, p. 164–166. Jefferson City, Mo., 1874.

winter rains. If, however, the leaves are kept perfectly dry, a large percentage of the nymphs fail to extricate themselves from the egg-shell. This observation suggests the possibility that the species may successfully pass the winter in the egg stage even in deciduous leaves and in its most northerly range, provided these leaves are sufficiently protected from freezing by a covering of dead leaves and snow.

### INCUBATION PERIOD.

Eggs have never been observed to hatch during the year they were deposited, and in the San Joaquin Valley they invariably pass the winter in the leaves on the citrus tree. The average duration of the egg stage, as determined in 1911 and 1912 from 68 eggs deposited between July 14 and August 6, was 286 days. Eggs deposited in July averaged about 290 days; those deposited in August, about 275 days. Those deposited later in the year undoubtedly have a shorter duration, since the period of hatching for all is short. In general, the incubation period lasts from the maximum period of deposition, about the middle of August, to the maximum period of emergence, which, in 1912, was about the middle of May, or 275 days.

### ENEMIES OF THE EGG.

A small chalcidid parasite, determined by Mr. J. C. Crawford as belonging to the genus Anastatus, is the most important, and indeed the only enemy of the egg discovered during the investigation. This parasite, though perhaps the most important natural check to the species, is much more effective in checking the angular-winged katydid, to which it largely confines its attacks. On March 22, 1912, a quantity of orange leaves, each containing one or more eggs of *S. furcata*, was gathered and kept in condition for the hatching of the eggs. On April 2 adult parasites began to emerge from these eggs and continued to do so for one and one-half months, or until May 18. The proportion of eggs parasitized in the lot under observation was 25 per cent. The eggs were taken at random from all parts of an orchard, and it seems reasonable to assume that fully 25 per cent of all the eggs in this orchard were parasitized.

*General appearance of adult parasites.*—The little parasites running over the orange leaves resemble small, winged black ants. They are very active, glossy black, reflecting metallic bronze-green in the sunlight. They have two pairs of membranous wings, the fore pair in the female being almost covered by a large, brownish spot; both pairs are transparent in the male. The female is about one-eighth inch long, the male considerably smaller. Only one parasite issued from a single katydid egg in any case observed. The insect escapes from the side of the parasitized egg. The oviposition of Anastatus has not been observed.

## The Young.

### GENERAL APPEARANCE.

The young katydids of this species vary in length from one-sixth to three-fourths inch, depending on their age. Immediately after issuing from the egg they are of a pale flesh color, without visible vestige of wings. The head and mouth parts are large in proportion to the rest of the body; the antennæ are long and slender and usually directed forward. The larger nymphs, with rudimentary wings or "wing-pads," are bright green, closely matching the color of the orange leaves on which they rest. They resemble somewhat the young of the short-horned grasshoppers (Acridiidæ), except for the long, slender antennæ. They usually remain motionless upon the leaves or move over to the side away from the observer when too closely approached. Ordinarily at the approach of danger they become perfectly motionless in every part and, simulating the leaf color closely, are readily overlooked. When sufficiently disturbed, however, they show ample power as leapers, and will jump a foot or more.

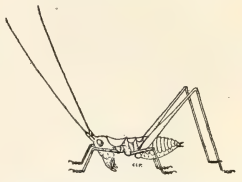

FIG. 4.—The fork-tailed katydid (*Scudderia furcata*): First-instar nymph. About three times natural size. (Original.)

FIG. 5.—The fork-tailed katydid: Basal segments of the antenna of first-instar nymph. Greatly enlarged. (Original.)

### DESCRIPTION OF INSTARS.

The young katydid grows slowly for an average period of about 73 days, during which time it molts six times before final emergence as a mature insect.

*First instar* (fig. 4).—Measurements: Greatest breadth of head, 1.10 mm.; greatest breadth of abdomen, 0.75 mm.; length of body, 4.10 mm.; length of pronotum, 0.70 mm.; length of posterior femur, 4.20 mm.; length of antenna, 10 mm. Just after issuance from the egg the nymph is of a pale flesh color. The legs, head, and thorax are irregularly marked with small blotches of red, purple, and white; the abdomen, with about ten longitudinal rows of minute red and white spots, the most conspicuous of which are one row of dark spots on either side of the middorsal yellow line and two rows of white spots below these on either side of the abdomen. The newly issued nymph is about one-sixth inch long. The fastigium, which is most prominent in this stage, is about one-half as long as the club-like basal segment of the antenna (fig. 5). Antenna with five distinct, broad white rings at regular intervals from tip to base, and with two narrow, less distinct white rings near the base; spaces between the rings dark purple. Head broad, thorax comparatively narrow, abdomen considerably enlarged toward tip. The lateral edges of sclerites

forming the dorsum of the mesothorax and metathorax appear as little flap-like, evenly rounded processes folded down over the upper portion of the episterna and epimera of their respective segments. These semicircular processes are the wing rudiments and are distinctly characteristic of this instar.

*Second instar* (fig. 6).—Measurements: Breadth of head, 1.3 mm.; greatest breadth of abdomen, 1.4 mm.; length of body, 6 mm.; length of pronotum, 1.1 mm.; length of posterior femur, 6.1 mm.; length of antenna, 14 mm. The markings on the body are the same as in the preceding instar, but the ground color of the abdomen is bright green, making the spots on it less conspicuous. The small, flaplike wing rudiments are now almost equilaterally triangular, with nearly pointed and but very slightly rounded tips. The bright green color of the abdomen and the triangular shape of the wing-pads readily distinguish this stage from the preceding one. Just after the first molt the nymph is about one-fourth inch long.

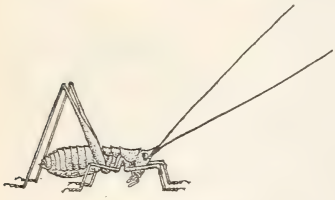

FIG. 6.—The fork-tailed katydid: Second-instar nymph. Somewhat more than twice enlarged. (Original.)

*Third instar* (fig. 7).—Measurements: Length of body, 7.4 mm.; length of pronotum, 1.55 mm.; length of posterior femur, 7.5 mm.; length of antenna, 17 mm. The general color and markings of the body are as in the second instar, the intensity of the green coloring varying in different individuals. In this and succeeding instars the head and abdomen are less broad compared with the thorax than in instars I and II. The wing rudiments are triangular as in the second instar, but their hind margins extend downward and very slightly forward, while the front margin extends more abruptly backward than in preceding stages, thus making the sides unequal in length. Faint evidences of wing-veins may be distinguished at this stage. Just after molting to this instar the nymph is about one-third inch long.

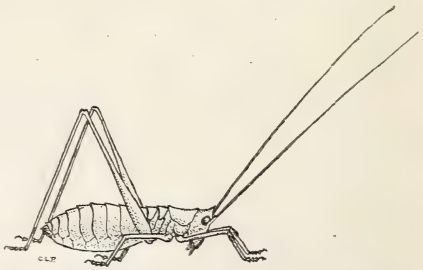

FIG. 7.—The fork-tailed katydid: Third-instar nymph. Three times natural size. (Original.)

*Fourth instar* (fig. 8).—Measurements: Length of body, 10 mm.; pronotum, 2.3 mm.; posterior femur, 10.8 mm.; antenna, 24 mm. Color as in preceding instar. Wing-pads appressed to sides of mesothorax and metathorax as in preceding instars, but both front and hind margins extending downward and backward; posterior pair reaching well over on the sides of the first abdominal segment. About eight veins can be readily distinguished in the hind wings and a few

are faintly visible in the forewings. The pronotum covers about one-half the dorsum of the mesothorax. The sexes can be distinguished in this stage by the appearance of the external genitalia. Just after the third molt the nymph is about two-fifths inch long.

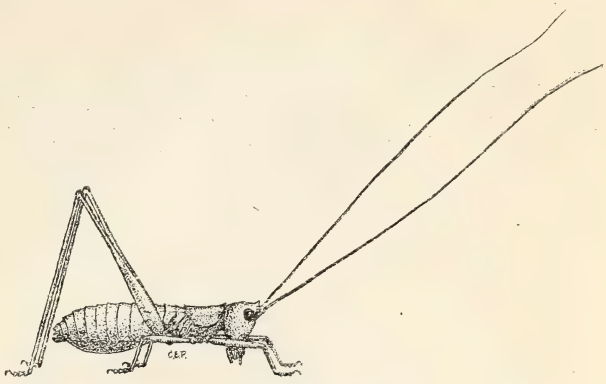

FIG. 8.—The fork-tailed katydid: Fourth-instar nymph. About three times natural size. (Original.)

*Fifth instar* (fig. 9).—Measurements: Length of body, 12.5 mm.; pronotum, 3.1 mm.; posterior femur, 13 mm.; antenna, 26 mm. In this instar the position occupied by the wing-pads is different from that in any of the earlier instars. They now lie partly over the abdomen in a tectiform position, this change being brought about by the previously outwardly exposed sides being brought out, upward, and in leaving the inner sides exposed roof-shape above the body. The tips of the posterior wing-pads now reach to the hind margin of the second abdominal segment; wing-pads similar in shape, in position relative to the body, and in venation to the adult wings. Pronotum completely covering the dorsum of the mesothorax. The young of this instar are about one-half inch long shortly after the molt.

FIG. 9.—The fork-tailed katydid: Fifth-instar nymph. About three times natural size. (Original.)

*Sixth instar* (fig. 10).—Measurements: Length of body, 16 mm.; pronotum, 4.5 mm.; posterior femur, 18.5 mm.; antenna, 3.9 mm. In this instar the nymphs resemble adults in almost every particular except the smaller size of the wings. Just after molting the wings extend rooflike over the abdomen to the ninth segment, the dorsal

edges meeting near their tips. With feeding and growth of the nymph the abdomen elongates without a corresponding growth of the wings, with the result that the latter reach only about to the sixth abdominal segment just before transformation to the adult. The prothorax extends slightly over the dorsum of the metathorax. The white rings on the antennæ, which have grown gradually fainter with each succeeding molt, are now but faintly visible. The external genitalia, the ovipositor in the female and the forked, supraanal spine in the male, appear to be almost as fully developed as in the adult. The nymph is about five-eighths inch long just after the molt to this instar.

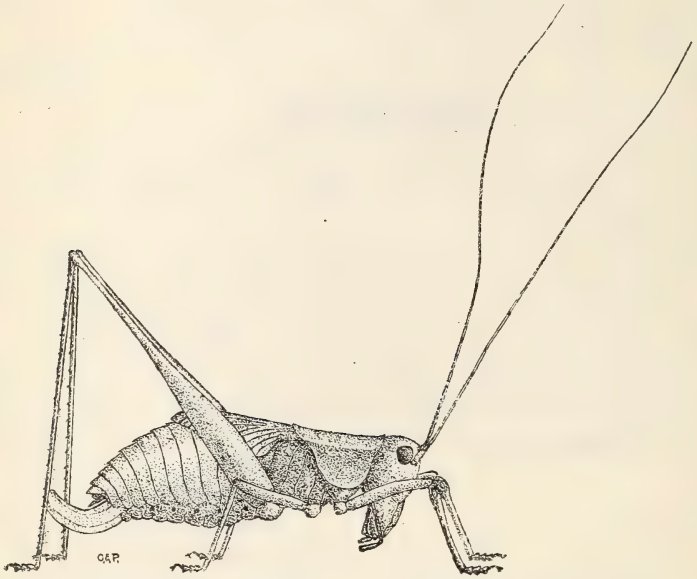

FIG. 10.—The fork-tailed katydid: Sixth-instar nymph. About three times natural size. (Original.)

DURATION OF INSTARS.

The duration of instars, averaged from all our records, was as follows: Instar I ranged from 10 to 35 days, with an average of 18.8 days; instar II ranged from 8 to 13 days, with an average of 9.7 days; instar III ranged from 4 to 12 days, with an average of 7.1 days; instar IV ranged from 6 to 10 days, with an average of 8.3 days; instar V ranged from 3 to 15 days, with an average of 10.4 days; instar VI ranged from 12 to 20 days, with an average of 14 days. The complete nymphal stage required from 58 to 88 days. Nymphs issuing early in the spring were slower to become adults than those issuing later when the average temperatures were higher.

MOLTING.

After feeding for from 1 to 3 weeks the nymph ceases to eat and remains sluggish for from 24 to 48 hours. The skin then splits along

the middorsal line from between the eyes to a point between the posterior wing-pads. The insect hangs helplessly, head downward, suspended by the posterior claws, and gradually works its way out of the dead skin. The head, thorax, fore-legs, intermediate legs, wings, abdomen, and hind legs are freed from the exuvium in the order named. During the entire process the antennæ are held lightly between the maxillary palpi and pulled and guided carefully from their position along the ventral surface of the body.

#### ENEMIES OF THE NYMPH.

A common gray jumping spider, determined by Mr. Nathan Banks, of the Bureau of Entomology, as *Thiodina puerperis* Htz., has been observed to capture the small nymphs of the first instar. This active, solitary spider is quite numerous on orange trees in the San Joaquin Valley, and feeds upon insects of several orders, injurious and beneficial alike. The very young spiders capture insects as minute as the citrus thrips.

In 1911 a small chipping sparrow was noted in some abundance among trees of various katydid-infested orchards, and was apparently very busily capturing katydids. Birds are undoubtedly the most important enemies of the katydid in this section.

### The Adult.

#### GENERAL APPEARANCE.

The adults (Pl. III, fig. 2) are dark green, their color blending almost perfectly with that of the orange leaves. They habitually seek the shady interior of the tree during the heat of the day, thus adding to the difficulty of discovery, even when fairly abundant. Their length is about 1½ inches from vertex to tip of wings. When they are at rest, the wings, which are narrow and rounded at the tips, are closely folded along the sides of the body. In flight the stiff, outstretched wings and the habit of sailing for considerable distances with scarcely any wing movement give them a fancied resemblance to a monoplane.

#### EMERGENCE AND MATING.

As a rule most of the nymphs transform to the adult stage early in the summer, though the exact time of beginning emergence varies more or less in different years. In 1912 adults were fairly numerous by June 15 and practically all of the insects were in the adult stage by July 5. In 1911 the period of emergence was slightly later than in 1912, and nymphs were found in the field until about July 17.

Mating usually takes place about 20 days after emergence, the time elapsing between the last molt and the first copulation varying from 14 to 40 days. Females which have recently mated can usually,

if not always, be detected by the extrusion near the base of the ovipositor of a bilobed translucent, jellylike mass of unknown character, which is visible for several hours.[1]

Specimens in captivity have mated as often as six times in a period of about 120 days. Union of the sexes perhaps occurs less often in the field. The stridulation note of the male is a short, soft rasp, usually given one, two, or three times in succession. The note is produced by rubbing the short, filelike process, extending diagonally across the under surface of the forewings, over the thin margin of the hind wings. At times it appears to be a sexual call, at other times merely a note of alarm; it is most persistent at night.

### OVIPOSITION.

Oviposition, which has been observed by the writers many times, has already been described in some detail by Riley.[2] Variations from Riley's account were noted in the orange groves near Lindsay, Cal., as follows: For a period of about 10 seconds the female generally cleanses, or possibly lubricates, the convex edge and tip of the ovipositor with her mouth before the deposition of each egg. The ovipositor is always held firmly between the mandibles from the moment its tip touches the edge of the leaf until the blade is finally withdrawn from the latter. As the ovipositor is forced between the leaf surfaces the two pairs of blades comprising it move slowly back and forth, alternately, over each other with a distinct though slight rotatory motion. The apical third of two of the blades is finely notched, sawlike, along the concave margin, the other pair being similarly notched along the convex margin. At the beginning of oviposition the ovipositor is worked into the leaf for almost its entire length, thus forming a pocket to contain the egg. Without pause the organ is then withdrawn to half its length, and the abdomen begins to expand and contract rhythmically, forcing the egg between the blades of the ovipositor into the cavity in the leaf. The complete operation of depositing one egg requires about four and one-half minutes.

*Rate of oviposition and number of eggs deposited by single females.*—A female of *Scudderia furcata* has been seen to deposit as many as 9 eggs in 45 minutes. This high rate of oviposition is not, however, long maintained, and after depositing such a number the female usually ceases to oviposit for from one to four days. Eggs are seldom deposited for more than three days in succession. During the summer

[1] Similar protrusions have been noted following mating in the females of other Locustidæ. The writers have observed it on the female of *Microcentrum rhombifolium* Sauss.; C. P. Gillette has seen and described it on *Anabrus simplex* Haldeman; R. E. Snodgrass has noted the phenomenon in connection with the mating of *Peranabrus scabricollis* Thomas; and it had previously been observed in *Scudderia furcata* Brunn. by A. N. Caudell.

[2] Loc. cit. Due to a misidentification the name here used is *Scudderia curvicauda*.

the usual number of eggs, from 1 to 3, are laid overnight, at which time oviposition mostly occurs. Oviposition decreases during the fall months and usually ceases entirely about midwinter. Females which have ceased to oviposit in winter may be induced to begin again by placing them in an artificially warmed atmosphere. Thus, one of a number of females which had ceased to oviposit about the middle of November, when taken from a temperature of 40° F., early in December, and placed in a room heated to 75° F., began to oviposit and laid 8 eggs in the course of an hour. A single female in the course of her life deposits, on an average, about 175 eggs. Infrequently individuals held in captivity from the middle of July to the following December have deposited about 230 eggs. The following complete individual records were obtained from specimens which emerged in captivity and were kept there, under nearly field conditions, until death:

TABLE I.—*Oviposition record of the fork-tailed katydid, Lindsay, Cal., 1912.*

| No. of specimen. | Number of eggs deposited. | No. of specimen. | Number of eggs deposited. |
|---|---|---|---|
| 1 | 169 | 10 | 206 |
| 2 | 172 | 11 | 74 |
| 3 | 121 | 12 | 140 |
| 4 | 174 | 13 | 230 |
| 5 | 114 | 14 | 87 |
| 6 | 64 | 15 | 142 |
| 7 | 78 | 16 | 239 |
| 8 | 132 | 17 | 61 |
| 9 | 57 | 18 | 159 |

Most of the eggs of this species are deposited during the period from the latter part of July to the last of September, though oviposition still occurs as late as the first week in December in warm winters, and adults have been found ovipositing as early as June 18.

### LENGTH OF LIFE OF ADULTS.

Adults reared in screened cages, protected from their natural enemies and given an abundance of fresh food daily, lived, on an average, 125 days, or a little over four months. In a few exceptional cases individuals lived from 150 to 160 days—162 days in the case of a single specimen being the record longevity.

### ENEMIES OF THE ADULT.

Birds undoubtedly play an important part in reducing the number of adults each year. Under field conditions adults are less numerous in October and November than in July and August, yet specimens protected by large screen cages live through October and most of November as actively as during the first few weeks of their adult life. In certain orchards where the infestation was particu-

larly bad in 1911 and 1912 large numbers of adult katydids disappeared in August and September. At about the same time large numbers of small birds of an undetermined species were noted in and about these orchards. These little birds were unquestionably responsible for the disappearance of katydids.

### Seasonal History.

As there is but one generation of the fork-tailed katydid annually, the duration of the life cycle is approximately one year. The average life cycle, as determined from a number of complete rearings in 1911 and 1912, was 367 days, ranging from 343 to 383 days. The first nymphs to appear issued about April 20, the majority issuing during May. Nymphs are most abundant in May and June, but have occasionally been seen as late as August 15. The first adults appear early in June, are fairly numerous by the last of June, and most abundant during July and August. They can be found without much difficulty in September and more rarely in October. The last specimens of the season were captured December 3. A few have been kept alive in screen cages until early January.

## THE ANGULAR-WINGED KATYDID.

### NATURE AND EXTENT OF INJURY.

The angular-winged katydid (*Microcentrum rhombifolium* Sauss.) somewhat closely resembles the fork-tailed katydid and is closely associated with the latter on orange trees in the San Joaquin Valley. It is, however, larger than the fork-tailed katydid and may be readily distinguished from that insect by its size, broader wings, and in the nymph by its hunchbacked appearance. Although responsible for a certain amount of injury to orange trees annually, it attacks only the foliage and rarely does enough damage to cause alarm. This insect has been present in Florida orange groves for years without, except in rare cases, causing sufficient damage to attract attention. This is also the case in California. The observations of the writers indicate that the minor position of the angular-winged katydid as a pest is largely due, first, to the high percentage of parasitism suffered by the eggs; and, second, to the fact that the insect does not attack the fruit. That it might injure the fruit if able to increase to the point of crowding is quite possible. The insect is also exposed to the attacks of various enemies, chiefly birds, because of its large size and slowness of movement. The first-instar nymphs feed principally if not wholly upon the leaf surface, removing merely a chlorophyll layer. Later stages gnaw clear through the leaves, filling them with ragged holes, and destroy a larger amount of foliage in proportion to their number than does the fork-tailed katydid. The insect has never been seen to attack blossoms or fruit.

### FOOD PLANTS.

In the San Joaquin Valley orange section the angular-winged katydid, like the forked-tailed katydid, confines itself all but exclusively to orange trees. Its eggs have been found a few times upon an undetermined native weed, the latter always growing near orange trees. Adults have been found upon grapevines adjoining an orange grove, and males have repeatedly been heard loudly stridulating in large pepper trees (*Schinus molle*) about Lindsay, Cal. According to Riley[1] an allied species, *Microcentrum retinerve* (Burm.), feeds upon a great variety of foliage, including oak, apple, and cherry.

### DISTRIBUTION.

The angular-winged katydid has apparently about as wide a range as *Scudderia furcata*, having been reported from the New England States, Florida, and California. It occurs throughout the central California citrus belt with the fork-tailed katydid, though it is not so often found because less numerous.

### LIFE HISTORY.

#### The Egg.

The egg (Pl. IV, fig. 1) may be described as follows: Length, 5.18 mm.; breadth, 2.47 mm.; thickness when first deposited, 0.5 mm.; thickness just before hatching, 2.2 mm. Color light grayish brown; elongate ovoid, flat to almost cylindrical laterally, depending upon the degree of development.

The eggs are glued in double rows along the sides of twigs from one-eighth to one-fourth inch in diameter. These selected twigs may be inside the leaf shelter of the tree or on the exterior. There may be from 3 to 28 or more eggs in a batch, each egg overlapping the one above it. The two rows always occur if more than one egg is deposited, each egg of one row alternating with an egg in the other row. The larger egg groups of this insect, composed of 24 or more eggs, each about one-fifth inch long, are decidedly conspicuous.

#### INCUBATION PERIOD.

The average duration of the egg stage is about 225 days. Eggs deposited the last of September hatch in about 228 days, while those deposited about the middle of October hatch in approximately 212 days. The time required for incubation thus depends upon the time of season deposited, the period of hatching being shorter than the period of deposition. Eggs laid from September 20 to September 30 hatched from May 10 to 15, while those deposited between October 20 and 30 hatched from May 15 to 20.

[1] Op. cit., p. 155–161.

### HATCHING.

When the egg is ready to hatch, the lateral halves split at their juncture along its edge for about one-third the length from the upper end, the nymph slowly forcing itself through the opening thus made.

### ENEMIES OF THE EGG.

The greatest natural check to the increase of the angular-winged katydid in California is the egg parasite, *Anastatus* sp., already referred to in connection with *Scudderia furcata*. Anastatus parasitizes a large percentage of all eggs deposited by this insect each year. It is quite usual to find large batches of katydid eggs, each egg showing the small, circular exit hole of the parasite (Pl. IV, fig. 1). It is, in fact, rare to find eggs of this katydid entirely free from evidence of parasitism. Anastatus oviposits in the katydid eggs in September and October, the larva feeding upon the egg contents during the remainder of the fall and the adult emerging the following spring. All reared specimens have emerged between March 19 and May 18. It seems probable that 80 per cent or more of all eggs deposited by *M. rhombifolium* are destroyed by this little insect. For example, a lot of eggs collected in widely separated locations in the fall of 1911 produced 43 adult Anastatus, representing 86 per cent parasitism. Of another lot of 109 eggs 35 per cent produced living parasites and the remainder failed to hatch.

## THE NYMPH.

### DESCRIPTION OF INSTARS.

The nymph of the angular-winged katydid may be easily distinguished from that of the fork-tailed katydid by its plump body and highly arched back, which gives it a decidedly humpbacked appearance. The nymphs vary in length from one-sixth to three-fourths inch, depending upon the stage of development. Their color is grass-green throughout, including the long, threadlike antennæ. There are six periods of development, or instars, which may be described as follows:

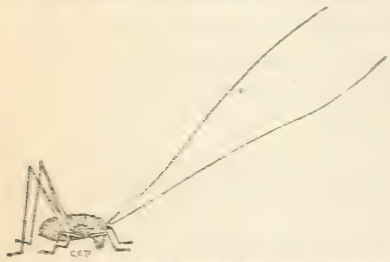

FIG. 11.—The angular-winged katydid (*Microcentrum rhombifolium*): First-instar nymph. Slightly over twice natural size. (Original.)

*First instar* (fig. 11).—Measurements: Length of body, 4 mm.; length of head (vertex to tip of jaws), 2 mm.; length of pronotum, 0.72 mm.; length of posterior femur, 4.75 mm.; length of posterior tibia, 5 mm.; length of antenna, 16 mm.; subovate, convex along dorsum and nearly flat along ventral surface. Color grass-green,

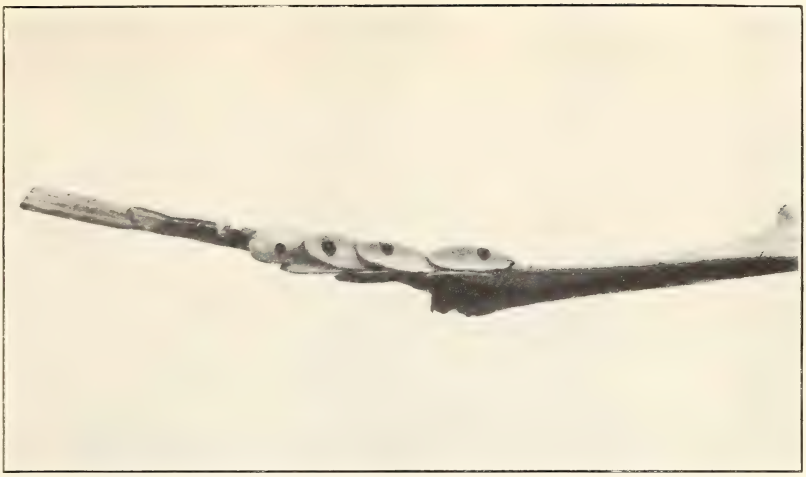

FIG. 1.—EGGS OF THE ANGULAR-WINGED KATYDID (MICROCENTRUM RHOMBIFOLIUM), SHOWING EXIT HOLES OF THE PARASITE, ANASTATUS SP. TWICE NATURAL SIZE. (ORIGINAL.)

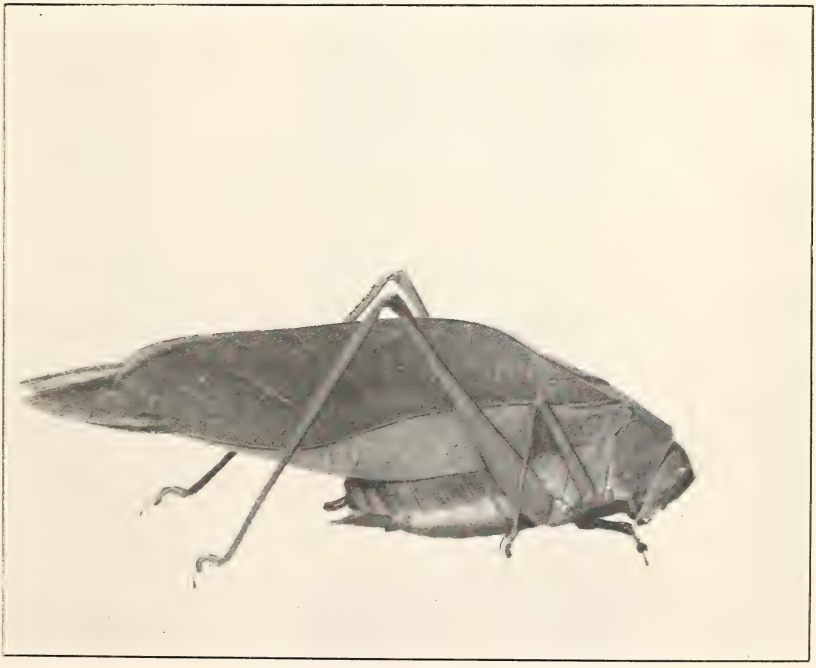

FIG. 2.—THE ANGULAR-WINGED KATYDID: ADULT MALE. THREE-FOURTHS ENLARGED. (ORIGINAL.)

THE ANGULAR-WINGED KATYDID.

FIG. 1.—A ROW OF SPRAYED ORANGE TREES BEFORE PICKING. [THE TREE IN FOREGROUND REPRESENTATIVE OF ALL SPRAYED TREES.] (ORIGINAL.)

FIG. 2.—VIEW IN AN EXPERIMENTAL ORCHARD IN CALIFORNIA. (ORIGINAL.)

with minute black dots in longitudinal rows, forming one crossrow upon each abdominal segment near hind margin; legs marked with more conspicuous black dots.

*Second instar* (fig. 12).—Measurements: Length of body, 6 mm.; length of head, 2.4 mm.; length of pronotum, 1.14 mm.; length of posterior femur, 5.8 mm.; length of posterior tibia, 6 mm.; length of antenna, 21.96 mm. Shape and color of body about as in first instar.

*Third instar* (fig. 13).—Measurements: Length of body, 7.5 mm.; length of head, 2.9 mm.; length of pronotum, 1.6 mm.; length of posterior femur, 8 mm.; length of posterior tibia, 8 mm.; length of antenna, 20.25 mm. Color and shape of body as before, except that black spots are less conspicuous.

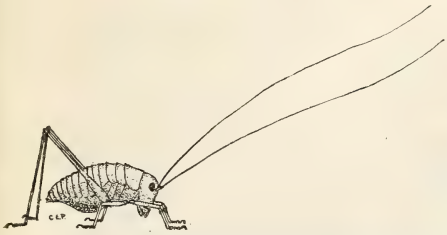

FIG. 12.—The angular-winged katydid: Second-instar nymph. Somewhat over twice natural size. (Original.)

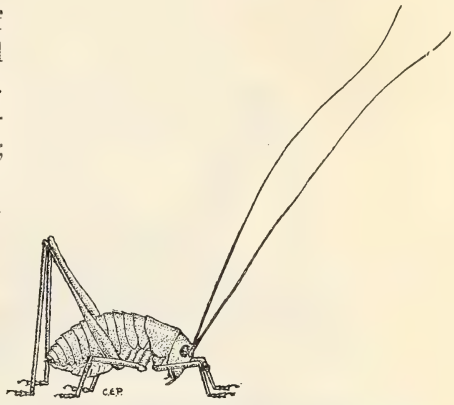

FIG. 13.—The angular-winged katydid: Third-instar nymph. Nearly three times natural size. (Original.)

*Fourth instar* (fig. 14).—Measurements: Length of body, 10 mm.; length of head, 3.75 mm.; length of pronotum, 2.66 mm.; posterior femur, 10 mm.; posterior tibia, 11 mm.; antenna, 20 mm. General color of body light green, merging into yellow on sides of abdominal segments; abdomen white beneath, or nearly so. Wing-pads sufficiently developed to be distinctly recognizable as such, hind pair showing well-developed veins and just overlapping first abdominal segment; tips of wing-pads directed downward and slightly backward.

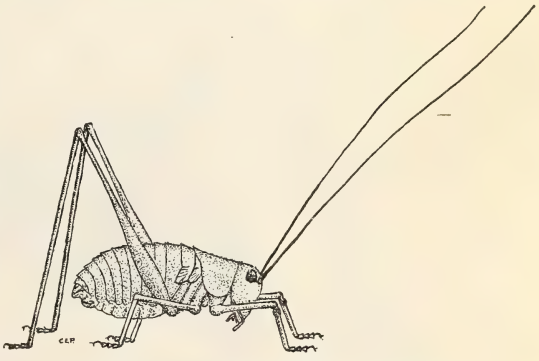

FIG. 14.—The angular-winged katydid: Fourth-instar nymph. Two and one-half times natural size. (Original.)

*Fifth instar* (fig. 15).—Measurements: Length of body, 15 mm.; length of head, 4.5 mm.; length of pronotum, 4 mm.; posterior femur, 13.25 mm.; posterior tibia, 14.5 mm.; antenna, 29 mm.

Color about as in preceding instar; body more strongly arched. Wing-pads more distinctly veined, their tips directed backward over the abdomen, reaching to middle of second segment.

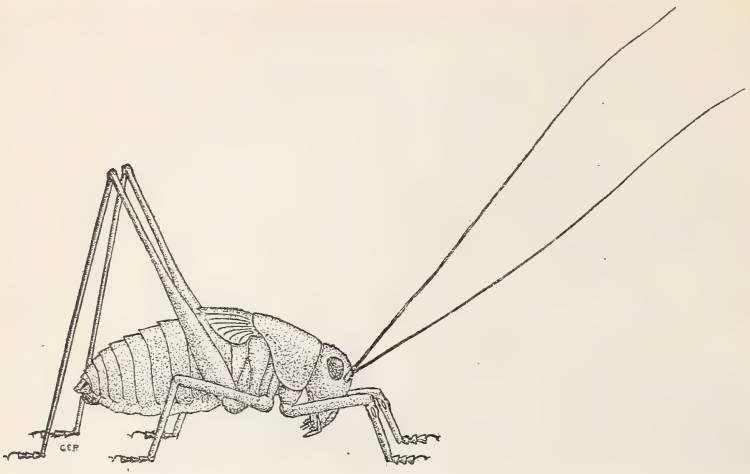

FIG. 15.—The angular-winged katydid: Fifth-instar nymph. Two and one-half times natural size. (Original.)

*Sixth instar* (fig. 16).—Measurements: Length of body, 17 mm.; length of head, 5.7 mm.; length of pronotum, 5 mm.; posterior femur, 16.5 mm.; posterior tibia, 17.7 mm.; antenna, 37.4 mm. Body strongly arched above, sloping about equally abruptly in both

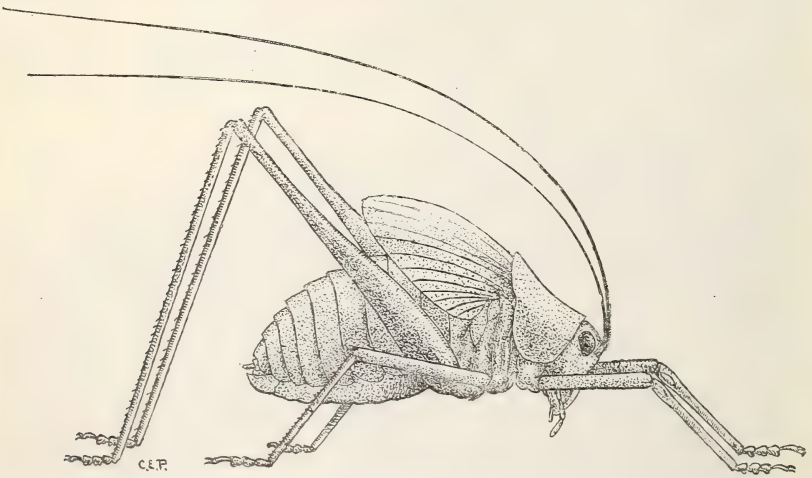

FIG. 16.—The angular-winged katydid: Sixth-instar nymph. Almost three times natural size. (Original.)

directions from second abdominal segment; wings projecting upward and backward at an angle from abdomen; tips considerably elevated above latter.

Nymphal instars each described from a single specimen shortly after molting.

#### DURATION OF INSTARS.

The average duration of the nymphal instars of the angular-winged katydid, as determined from a number of individual rearings, was as follows: Instar I, 13.8 days; instar II, 8.6 days; instar III, 9.5 days; instar IV, 10.2 days; instar V, 13.7 days; instar VI, 17.2 days. The average duration of the complete nymphal stage is therefore 73 days, or about 2½ months. Molting is accomplished in about the same manner as by the fork-tailed katydid (see pp. 10–11. The nymph always eats the greater part of its cast skin after each molt, rejecting only the mandibles, claws, and certain hard parts of the head cast.

### The Adult.

#### GENERAL APPEARANCE.

The body of the adult is broad and compact, and comparatively very wide dorsoventrally (Pl. IV, fig. 2). The humpbacked appearance so characteristic of the later stages of the nymph is retained, but to a lesser degree, owing to the broadly rounded angle of the forewings. The hind wings extend the full length of the body beyond the tip of the abdomen. The color is uniform grass-green over most of the body, becoming yellowish green on the ventral surface. The insect is fully 2 inches long, the wings measuring, when spread as for flight, about 3½ inches.

#### MATING.

Mating rarely or never occurs earlier than 18 days after emergence, and the period between emergence and the first union of the sexes ranges from 18 to 26 days. Coitus is succeeded by the extrusion of a small, bilobed mass of albuminous material, which, as in *Scudderia furcata*, may be seen clinging to the abdomen at the base of the ovipositor in the female for several hours subsequent thereto. The favorite time for mating is at night, when the males are very active and may often be heard sending forth a loud and sustained clatter for several hours at a time. The stridulating note, once heard, is readily recognized, and to trace it to its source will often disclose both male and female katydids, as stridulation appears to be closely connected with courtship. The stridulating song of an allied species, *Microcentrum retinerve* Burm., has been described by Riley as consisting of "a series of from 25 to 30 raspings, as of a stiff quill drawn across a file" at the rate of "about five of these raspings or trills per second, all alike, and with equal intervals, * * * the whole strongly recalling the slow turning of a child's rattle." This description is equally applicable to *M. rhombifolium*.

#### OVIPOSITION AND LENGTH OF ADULT LIFE.

In captivity females have deposited from 3 to 123 eggs each during

the course of life, and in the orchard under normal conditions they probably deposit more than the maximum number here given, since on one occasion 133 eggs, showing advanced development, were removed from the ovisac of a female which had not oviposited during her entire life in captivity. The number of eggs laid at one time varied from 3 to 28. The adults live from three to three and one-half months, and are present in the orchard almost continuously from the middle of August to the middle of November. Adults lived in screen cages from 85 to 111 days.

### Seasonal History.

Most of the eggs of this species are deposited during September and October, and all eggs secured from females in captivity in 1911 and 1912 were deposited between September 4 and October 29. The eggs hatching the following spring, the nymphs make their appearance about the first of May. They reach the maximum abundance between May 15 and July 15 and will seldom be seen after the middle of August. Adults are most numerous during the period from August 15 to October 15; they are scarce in November and rare in December, finally disappearing entirely in January.

## CONTROL OF KATYDIDS ON ORANGES.

Several methods have been suggested for the control of katydids on oranges, among which the following have been found to be impractical: Destroying the nymphs by hand; gathering by hand and destroying the eggs; poisoning by the use of trap crops or by poisoned baits. It would be extremely difficult, if not impossible, to find any large percentage of eggs or nymphs, and the method would certainly prove too slow and tedious. The katydids can not be attracted from the fruit and foliage of the orange by any crop or bait while such an abundance of food so much to their liking is always at hand. Unless practically forced to quit the orange tree, they spend their entire lives upon the tree on which they are born.

### SPRAYING EXPERIMENTS.

Spraying with arsenicals is generally considered to be impractical for the control of grasshoppers and locusts because of the large dose necessary to kill these robust insects and the difficulty of applying such a dose evenly and with safety to the trees. These objections would doubtless hold with the citrus katydids if the spraying were done after the insects had reached an advanced nymphal or the adult stage. They do not hold, however, when the trees are properly sprayed while the insects are still largely in the first, second, or third nymphal instars.

### Preliminary Tests with Arsenicals.

Four groups of 10 Washington navel trees each were sprayed on April 15, 1912, for the purpose of determining the maximum strength of the different arsenicals that could be used with safety to the trees and to compare the adhesive qualities of the insecticides. The spraying was done in bright, warm weather and the trees were thoroughly drenched. The test trees were examined on April 19, and although covered with tender, new leaves not the slightest trace of burning resulted. Subsequent examinations in no case revealed burning or damage resulting from the spray application. It was later found safe to use considerably stronger solutions of the arsenicals, the maximum strengths of which were (1) arsenite of zinc, 2 pounds (powdered) per 100 gallons of water, and (2) arsenate of lead, 8 pounds (dry) per 100 gallons of water. The distribution of the arsenicals over the leaf surface after the spray dried did not seem entirely satisfactory, especially on the young leaves, whose waxy surface had caused the water to gather in drops, leaving the poison in spots. The addition of lime-sulphur solution to the arsenical sprays and the regulation of the nozzles so as to deliver a moderately fine spray remedied this objection.

### Plan of Experiments.

The principal spraying experiments conducted against the katydids are outlined in Table II. Each of the sprayed plats consisted of two rows of 33 trees each, or 66 trees to the plat. Three pairs of rows of trees extending through the midst of the sprayed area and the trees adjoining the sprayed area on the west were left unsprayed as checks. (See experimental orchard, Pl. V, fig. 2.)

Table II.—*Plan of spraying experiments against citrus katydids, Lindsay, Cal., 1912.*

| No. of plat. | Insecticides in gallons and pounds per 100 gallons of water. | | |
|---|---|---|---|
| | Lime-sulphur solution. | Arsenite of zinc. | Arsenate of lead. |
| | *Gallons.* | *Pounds.* | *Pounds.* |
| 1 | 2 | 2 | ..... |
| 2 | 2 | 3 | ..... |
| 3 | 2 | 4 | ..... |
| 4 | 2 | ..... | 4 |
| 5 | 2 | ..... | 6 |
| 6 | 2 | ..... | 8 |
| 7 | ..... | 2 | ..... |
| 8 | ..... | 3 | ..... |
| 9 | ..... | ..... | 4 |

Plats 1, 2, 4, and 5 received two applications containing lime-sulphur and arsenicals and one application of lime-sulphur alone; plats 3 and 6 received one application containing both lime-sulphur and arsenicals and two applications of lime-sulphur alone; plats 7, 8, and 9 received only two applications of arsenicals alone. The chief purpose of adding lime-sulphur to the sprays was to make them effective against the citrus thrips. The third application was directed solely against this insect, only two applications of arsenicals being made in any case. The applications were timed, also, partly with a view to controlling thrips as well as katydids, and the dates of beginning were May 22, June 3, and June 24, respectively.

### Results.

The efficiency of the sprays in killing katydids was determined by a comparison of the number of living insects occurring in the sprayed and unsprayed blocks some days after spraying was completed. Arsenite of zinc at the rate of 2 pounds per 100 gallons killed 93.1 per cent of the fork-tailed katydids and 100 per cent of the angular-winged katydids. Arsenate of lead at the rate of 4 pounds per 100 gallons killed 100 per cent of the insects in each case.

The results of the season's spraying work were principally manifested in three ways: (1) By preventing a complete loss of a certain amount of fruit by dropping; (2) by almost complete prevention of katydid injury to the mature fruit and the leaves and reduction in the amount and severity of thrips injury; and (3) by improvement in the amount and vigor of growth of the sprayed over the unsprayed trees.

#### PREVENTION OF DROPPING.

During July, fruits injured by both katydids and thrips were very conspicuous on the unsprayed trees, at once attracting the attention when one entered the orchard. While in the orchard on August 9 the senior writer noted that badly injured outside fruit was decidedly less in evidence on unsprayed trees than had been previously the case. The cause of this disappearance of fruit was soon found; it had fallen to the ground. By counting all the fruit on and under 10 unsprayed trees it was found that 18.7 per cent of the crop had fallen from these trees. Examination of the fruit which had fallen, for the location of the insect injury, disclosed 62.8 per cent of it full of holes, while 83.3 per cent were severely marked by thrips. Many of these fruits had been eaten into near the point of attachment to the stems. However, much of the dropped fruit during this period was caused by thrips injury, the most severe dropping due to katydids coming earlier in the season when very small fruits were chewed to pieces by these insects. At all events, the 18.7 per cent of dropped

fruit at this time was principally due to katydids and thrips. No fruits had fallen at this time from sprayed trees, as examination of the ground under 15 trees disclosed.

At picking time it became evident that a much larger saving of fruit than that just indicated resulted from spraying. During October and November all the fruit of all sprayed plats and checks was counted, from which it was found that from 60 to 100 per cent more fruit was produced in each of the sprayed plats than in their unsprayed checks. (See Pl. V, fig. 1.) The trees of the different plats varied greatly in size and condition, however, and it was therefore necessary to know how many trees in each plat produced the fruit of that plat. By eliminating the stunted, rebudded, and dead trees, resets, and blank spaces in each plat it was found that the full-bearing, unsprayed trees matured only 54.2 per cent, or just a little over half as many oranges per tree as the full-bearing trees of the sprayed plats. The saving of crop in all sprayed plats taken together due solely to spraying was, therefore, practically 100 per cent. A greater saving was effected in plats sprayed with lime-sulphur and arsenicals mixed than in those sprayed with arsenicals alone, the former producing a little over twice as much and the latter only one and one-half times as much fruit per tree as the checks.

### PREVENTION OF INJURY TO MATURED FRUIT.

The results of the spraying experiments in preventing katydid injury to the final crop of fruit were determined by examination, in the field at picking time, of all oranges in all plats. For convenience of reference these results are shown in Table III.

TABLE III.—*Results of spraying experiments with lime-sulphur and arsenicals in preventing injury to oranges by katydids, Lindsay, Cal., 1912.*

| Insecticides and dilution. | Sprayed fruit. | | Unsprayed fruit. | |
|---|---|---|---|---|
| | Percentage of sound fruit. | Percentage of culled fruit. | Percentage of sound fruit. | Percentage of culled fruit. |
| Plat 1: Arsenite of zinc, 2 pounds; lime-sulphur, 2 gallons, per 100 gallons water | 100.00 | | | |
| Plat 2: Arsenite of zinc, 3 pounds; lime-sulphur, 2 gallons, per 100 gallons water | 99.99 | 0.01 | 80.5 | 19.4 |
| Plat 3: Arsenite of zinc, 4 pounds; lime-sulphur, 2 gallons, per 100 gallons water | 99.85 | .14 | | |
| Plat 4: Arsenate of lead, 4 pounds; lime-sulphur, 2 gallons, per 100 gallons water | 99.85 | .14 | 80.9 | 19.0 |
| Plat 5: Arsenate of lead, 6 pounds; lime-sulphur, 2 gallons, per 100 gallons water | 99.86 | .13 | | |
| Plat 6: Arsenate of lead, 8 pounds; lime-sulphur, 2 gallons, per 100 gallons water | 99.77 | .22 | 82.3 | 17.6 |
| Plat 7: Arsenite of zinc, 2 pounds, per 100 gallons water | 99.92 | .07 | | |
| Plat 8: Arsenite of zinc, 3 pounds, per 100 gallons water | 99.92 | .07 | | |
| Plat 9: Arsenate of lead, 4 pounds, per 100 gallons water | 99.84 | .15 | | |
| Average | 99.88 | .11 | 81.45 | 18.55 |

As shown in Table III, two applications of arsenite of zinc, at the rate of 2 pounds per 100 gallons plain water (plat 7) or dilute lime-sulphur solution (plat 1), gave practically the same results as one application at the rate of 4 pounds per 100 gallons (plat 3), being sufficient in each case to kill the katydids and insure approximately 100 per cent sound fruit. Two applications of arsenate of lead, at the rate of 4 pounds per 100 gallons plain water (plat 9) or dilute lime-sulphur solution (plat 4), were practically as effective as the arsenite of zinc and gave just as good results as when used at the rate of 8 pounds per 100 gallons with but one application (plat 6).

The addition of lime-sulphur to the arsenicals, besides being absolutely essential where it is desired to control both katydids and the citrus thrips, increased the adhesive quality of the arsenicals and facilitated their even distribution over the leaves and fruit. This was especially noted after a slight rain, occurring May 25, when the combination sprays appeared to be very little affected. Lime-sulphur solution itself without the addition of arsenicals proved deterrent to the katydids and measurably reduced the amount of injury to the fruit. It also, therefore, appears to have some insecticidal value against these insects.

## RECOMMENDATIONS.

On the basis of the foregoing results the writers make the following recommendations for the control of katydids on oranges in the San Joaquin Valley:

1. Two applications of arsenite of zinc at the rate of 2 pounds per 100 gallons of water; or,

2. Two applications of arsenate of lead at the rate of 4 pounds per 100 gallons of water.

The first application should be made, at the latest, immediately after most of the petals have fallen; the second application, from 10 days to 2 weeks after the first. If it seems desirable to spray for the citrus thrips also, lime-sulphur should be added to the above at the rate of 2 gallons per hundred, and a third application of lime-sulphur only, at the same dilution, should be made about two or three weeks after the second.

The cost of spraying will vary somewhat according to size of trees, cost of labor, team hire, insecticides, etc., but with ordinarily good management will not exceed $5 per acre.

WASHINGTON : GOVERNMENT PRINTING OFFICE : 1915